Code : 102101

B.Tech 1st Semester Exam., 2019
(New Course)

PHYSICS

(Electromagnetism)

Time : 3 hours *Full Marks* : 70

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **NINE** questions in this paper.*

*(iii) Attempt **FIVE** questions in all.*

*(iv) Question No. **1** is compulsory.*

1. Answer any *seven* of the following questions : 2×7=14

(a) With necessary expression, explain standing wave ratio.

(b) Calculate the inductance of a solenoid of 400 turns wound on a cylindrical tube of 10 cm diameter and 50 cm length. Assume the solenoid is in air.

(c) What do you mean by magnetic torque and magnetic dipole moment?

(d) Find the conduction and displacement current density of a material for which $\sigma = 3 \cdot 0 \frac{S}{m}$, $\varepsilon_r = 2$ and the electric field intensity is 300 cos 10^{10} t V/m.

(e) What do you mean by skin effect?

(f) Differentiate among linear, elliptical and circular polarization.

(g) State and explain the Lorentz's force equation.

(h) An EM wave has electric component given by

$$E = E_0 \cos(\omega t - \beta z)\,(\hat{a}_x + \hat{a}_y)\ \text{V/m}$$

Comment on polarization of the wave.

(i) Explain the terms motional e.m.f. and transformer e.m.f.

2. Answer any *two* of the following questions : 7×2=14

(a) Express the vector

$$\vec{B} = \frac{10}{r}\vec{a}_r + r\cos\theta\,\vec{a}_\theta + \vec{a}_\varphi$$

in Cartesian and cylindrical coordinates. Also evaluate B (–2, 3, 1) and B (5, $\pi/3$, –5).

(b) Show that Cartesian components of E and H satisfy the three-dimensional wave equation using Maxwell's equations in a dielectric.

(c) Derive an expression for $\vec{E}$ and V for a spherical volume of radius a having a volume charge density $\rho = \rho_0 \left(\frac{r}{a}\right)^{\frac{3}{2}}$, where r is the radial distance from the centre of the sphere.

3. Answer any *two* of the following questions : 7×2=14

(a) Derive the boundary conditions for electrostatic field intensity and electric flux density at *(i)* the interface between two dielectrics and *(ii)* the interface between a perfect conductor and a dielectric.

(b) A long spherical cloud of radius r has a uniform volume charge distribution of ρ_v. Calculate the potential distribution and the electric field at any point in space using Poisson's and Laplace's equations.

(c) A homogeneous dielectric ($\varepsilon_r = 2{\cdot}5$) fills region $1(x < 0)$ while region $2(x > 0)$ is free space.

(i) If $D1 = 12\bar{a}_x - 10\bar{a}_y + 4\bar{a}_z$ nC/m^2, find $D2$ and $\theta 2$.

(ii) If $E2 = 12$ V/m and $\theta = 60°$, find $E1$ and $\theta 1$.

4. Answer any *two* of the following questions : 7×2=14

(a) Write and explain Maxwell's equations for a linear, homogeneous medium in terms of E_s and H_s and also write the Maxwell's equation in a source-free region.

(b) In a medium characterized by $\sigma = 0$, $\mu = \mu_0$, ε_0 and

$$E = 20 \sin(10^8 t - \beta z)\, a_y \text{ V/m}$$

Calculate β and H.

(c) For sea water with $\sigma = 5$ mho/m and $\varepsilon_r = 80$, $\mu = \mu_0$, find the distance a radio signal can be transmitted at 25 KHz and 25 MHz; if the range is taken to be the distance at which 90% of the wave amplitude is attenuated.

5. Answer any *two* of the following questions : 7×2=14

(a) (i) State Ampere's circuit law.

(ii) A hollow conducting cylinder has inner radius a and outer radius b and carries current I along the positive z-direction. Find H everywhere.

(b) A current of 0·4 A in the a_z direction in free space is in a filament parallel to the z-axis and passing through the point (2, –4, 0). Find $\overline{H}$ at (0, 1, 0) if the filament lies in the interval :

(i) $-\infty < z < \infty$

(ii) $-3 < z < 3$

(iii) $0 < z < \infty$

(c) Determine the gradient and also find the Laplacian of the scalar fields given below :

(i) $V = e^{-z}\sin 2x\cosh y$

(ii) $U = \rho^2 z\cos 2\phi$

(iii) $W = 10r\sin^2\theta\cos\phi$

6. Answer any *two* of the following questions : 7×2=14

(a) What is a lossy dielectric? Derive the electromagnetic field equation in a lossy dielectric and explain what is meant by loss tangent.

(b) For a linear, isotropic and homogeneous magnetic medium, show that

$$M = \frac{\chi_m}{\mu_0(1+\chi_m)}B$$

(c) Determine the self-inductance of a coaxial cable of inner radius a and outer radius b.

7. Answer any *two* of the following questions : 7×2=14

(a) A parallel-plate capacitor with plate area $5\,cm^2$ and plate separation of 3 mm has a voltage $50\sin 10^3 t$ volt applied to its plates. Calculate the displacement current assuming $\varepsilon = 2\varepsilon_0$.

(b) In a lossless dielectric for which $\eta = 60\pi$, $\mu_r = 1$ and $H = -0\cdot1\cos(\omega t - z)a_x + 0\cdot5\sin(\omega t - z)a_y$ A/m, calculate ε_r, ω and E.

(c) A uniform plane wave propagating in a medium has

$$E = 2e^{-\alpha z} \sin(10^8 t - \beta z) a_z \text{ V/m}$$

If the medium is characterized by $\varepsilon_1 = 1$, $\mu_r = 20$ and $\sigma = 3$ S/m, find α, β and H.

8. Answer any *two* of the following questions : 7×2=14

(a) Determine a uniform line charge of 16 nC/m is located along the line defined by $y = -2$, $z = 5$. If $\varepsilon = \varepsilon_0$, find (i) $\vec{E}$ at $P(1, 2, 3)$, (ii) $\vec{E}$ at that point in the $z = 0$ plane where the direction of E is given by $\frac{1}{3}\hat{y} - \frac{2\sqrt{2}}{3}\hat{z}$.

(b) A uniform plane EM wave with field varying sinusoidally in medium is incident normally on the surface of medium. Derive the expression for the reflection and refraction coefficients.

(c) Obtain Poynting theorem for conservation of energy in an EM field and discuss the physical significance of each term in resulting equation.

9. Answer any *two* of the following questions : 7×2=14

(a) Obtain an expression for the electric field intensity at any point P on the y-axis due to semi-infinite line charge placed along x-axis with a linear charge density ρ_l C/m.

(b) A solenoid of radius 4 mm and length 2 cm has 150 turns/m and carries current 500 mA. Find—

(i) $|H|$ at the centre;

(ii) $|H|$ at the ends of the solenoid.

(c) Determine whether the following potential equations satisfy Laplace's equation or not :

(i) $V = 2x^2 - 4y^2 + z^2$

(ii) $V = r^2 \cos\phi + \theta$

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